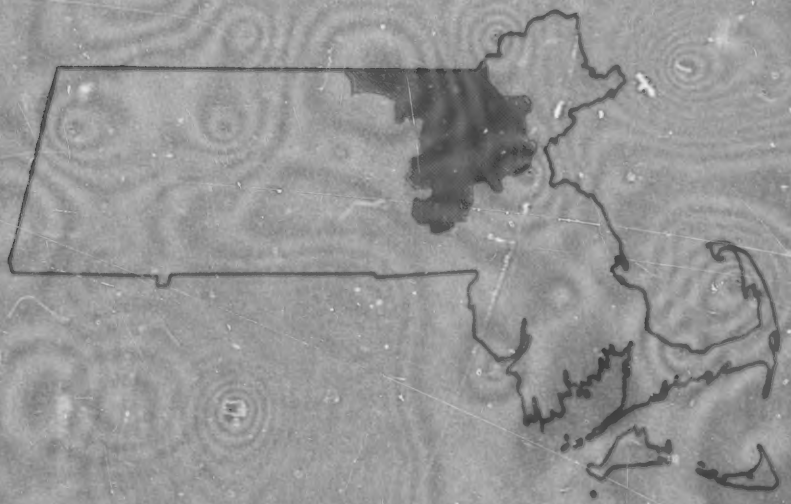
JUL 1986
JUN 16 1986
FEM 1.209: 230199
COMPLETED

FLOOD INSURANCE STUDY

ORIGINAL



TOWN OF LINCOLN, MASSACHUSETTS
MIDDLESEX COUNTY

JUNE 17, 1986

Federal Emergency Management Agency

COMMUNITY NUMBER -250199

BEST COPY AVAILABLE

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
	1.1 Purpose of Study	1
	1.2 Authority and Acknowledgements	1
	1.3 Coordination	2
2.0	AREA STUDIED	2
	2.1 Scope of Study	2
	2.2 Community Description	4
	2.3 Principal Flood Problems	5
	2.4 Flood Protection Measures	8
3.0	ENGINEERING METHODS	9
	3.1 Hydrologic Analyses	10
	3.2 Hydraulic Analyses	11
4.0	FLOOD PLAIN MANAGEMENT APPLICATIONS	12
	4.1 Flood Boundaries	13
	4.2 Floodways	13
5.0	INSURANCE APPLICATION	18
	5.1 Reach Determinations	18
	5.2 Flood Hazard Factors	19
	5.3 Flood Insurance Zones	19
	5.4 Flood Insurance Rate Map Description	20
6.0	OTHER STUDIES	20

BEST COPY AVAILABLE

7.0 LOCATION OF DATA..... 22

8.0 BIBLIOGRAPHY AND REFERENCES..... 22

FIGURES

Figure 1 - Vicinity Map..... 3

Figure 2 - Floodway Schematic..... 17

TABLES

Table 1 - Summary of Discharges..... 11

Table 2 - Floodway Data..... 14-16

Table 3 - Flood Insurance Zone Data..... 21

EXHIBITS

Exhibit 1 - Flood Profiles

Sudbury River.....	Panel 01P
Farrar Pond Brook.....	Panels 02P-03P
Farrar Pond/Pole Brook.....	Panels 04P-08P
Hobbs Brook.....	Panels 09P-10P
Stony Brook.....	Panels 11P-14P
Valley Pond.....	Panel 15P

Exhibit 2 - Flood Boundary and Floodway Map Index

Exhibit 3 - Flood Boundary and Floodway Map..... Panels 250199 0001-0003

PUBLISHED SEPARATELY:

Flood Insurance Rate Map Index

Flood Insurance Rate Map..... Panels 250199 0001C-0010C

BEST COPY AVAILABLE

FLOOD INSURANCE STUDY
TOWN OF LINCOLN, MASSACHUSETTS

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study investigates the existence and severity of flood hazards in the town of Lincoln, Middlesex County, Massachusetts, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study will allow Lincoln to continue participation in the regular program of flood insurance by the Federal Emergency Management Agency (FEMA) with the most current data. Local and regional planners will use this study in their efforts to promote sound flood plain management.

In some states or communities, flood plain management criteria or regulations may exist that are more restrictive or comprehensive than those on which these federally-supported studies are based. These criteria take precedence over the minimum federal criteria for purposes of regulating development in the flood plain, as set forth in the Code of Federal Regulations at 44 CFR, 60.3(d). In such cases, however, it shall be understood that the state (or other jurisdictional agency) shall be able to explain these requirements and criteria.

1.2 Authority and Acknowledgments

The source of authority for this Flood Insurance Study is the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses for the determination and delineation of flood plains for this study were originally performed by Harris-Toups Associates for the FEMA, under Contract No. H-4024. This work was completed in May 1977 and resulted in the publication of the Lincoln Flood Insurance Study (Reference 1).

The hydraulic analyses for this study were performed by Schoenfeld Associates, Inc. for the FEMA, under Contract No. EMW-C-0280. They were limited to recalculating the flood profiles of Stony Brook and recalculating all floodways based upon the availability of more recent information. In addition, the flood plains and floodways of all streams studied in detail in Lincoln were delineated on topographic maps obtained from the Town of Lincoln (Reference 2). This work, which was completed in March 1983, covered all flooding sources affecting the Town of Lincoln.

BEST COPY AVAILABLE

1.3 Coordination

Streams requiring a detailed study were identified at a meeting attended by representatives of the study contractor, the FEMA and of the town of Lincoln on August 30, 1979.

On April 24, 1984, the results of the study were reviewed at the final meeting attended by representatives of the study contractor, FEMA, and community officials. The study was acceptable to the community.

2.0 AREA STUDIED

2.1 Scope of Study

This Flood Insurance Study covers the incorporated area of the town of Lincoln, Middlesex County, Massachusetts. The area of study is shown on the Vicinity Map (Figure 1).

The limits of the detailed and approximate studies in Lincoln were determined by the FEMA with community and study contractor consultation at the meeting in August 1979.

The flooding sources studied by detailed methods are listed below:

a. The Sudbury River, along the corporate limits with Concord;

b. Farrar Pond/Pole Brook, from the confluence with the Sudbury River to Lincoln Road (State Route 126);

c. Farrar Pond Brook, from Farrar Pond to the small unnamed pond south of Mount Misery;

d. Hobbs Brook, from the Lexington-Lincoln corporate limits (at the Cambridge Reservoir) to a point 0.5 miles upstream of the Lincoln corporate limits;

e. Stony Brook, from a point 0.1 mile south of Tower Road to Sandy Pond; and

f. Valley Pond, from the Lincoln-Waltham corporate limits to the upper end of the pond.

Portions of the following streams were studied by approximate methods: Farrar Pond Brook, Pole Brook, Stony Brook, Hobbs Brook and several unnamed streams.

Approximate methods of analyses were used to study those areas having a low development potential or a minimal flood hazard. The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development or proposed construction for the next five years, through March 1988.

BEST COPY AVAILABLE

FIGURE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

APPROXIMATE SCALE

4 0 4 8 12 MILES

VICINITY MAP

BEST COPY AVAILABLE

2.2 Community Description

The town of Lincoln is located in eastern Middlesex County in northeastern Massachusects 13 miles northwest of Boston. It is bordered by the town of Bedford to the north, the town of Lexington and the city of Waltham to the east, the towns of Wayland and Weston to the south, and the town of Concord to the west. The total land area contained within the town limits is 14.92 square miles. According to U.S. Census Bureau figures, the population has decreased approximately six percent from 7,567 in 1970 to 7,102 in 1980 (Reference 3).

Much of the Lincoln area is undeveloped wetland or forest lands. Most buildings are located along Lincoln and Bedford Roads. The topography is low rolling hills, interspersed with swampy areas. Streams are fairly flat and, except for the Sudbury River, have small drainage areas within the town. These characteristics contribute to low runoff rates, and generally low flood peaks (Reference 1).

The general soil map of the Soil Conservation Service (SCS) classifies thirty percent of Lincoln's soil in the Hinckley-Enfield-Windsor Association, which is a deep, well-drained sandy loam. Approximately 23 percent of the soil is Carston-Narragansett muck (Reference 1).

The climate in Lincoln is moderate, with a mean annual precipitation of 46.82 inches. The temperature ranges from a mean of 26.2°F in January to a mean of 71.1°F in July (Reference 4).

West Lincoln is in the watershed of the Concord River system. The southern and eastern portions of Lincoln are within the drainage area of the Charles River basin. Wetland areas include the Sandy Pond Swamp, the marsh along the Boston and Maine Railroad and the Hobbs Brook Swamp (Reference 1).

The Sudbury River, an integral part of the Sudbury-Assabet-Concord (SaAsCo) watershed, forms the corporate limits between Lincoln and Concord. The river originates in the communities of Westborough, Ashland, and Hopkinton, and flows through the communities of Framingham, Sudbury, and Wayland before entering Lincoln and Concord and joining with the Assabet River 3.65 miles downstream of the corporate limits to form the Concord River. The Sudbury River, like the Concord River, has a wide floodplain along its course, much of which has been preserved as the Great Meadows National Wildlife Refuge (Reference 1).

Farrar Pond, a man-made pond, lies at the confluence of Pole Brook and Farrar Pond Brook and flows into the Sudbury River. Farrar Pond Brook originates in the swamplands near Baker Bridge Road, in the western section of Lincoln. It crosses

BEST COPY AVAILABLE

South Great Road (State Route 117) and flows into Farrar Pond. Pole Brook originates near Hathaway Hill in the southwest corner of Lincoln. It crosses Lincoln Road (State Route 126) and flows into Farrar Pond.

Hobbs Brook flows easterly across Mill Street from its origin in the swamp areas north of State Route 2 and east of Jupiter Ridge and then enters the Cambridge Reservoir.

Stony Brook has its origin in Sandy Pond. From Sandy Pond, the stream flows southerly past the Brooks, Smith, and Hartwell Schools, and crosses Lincoln and Tower Roads, before entering the community of Weston.

The swampy area north of Conant Road drains into Valley Pond, a man-made recreational pond. Valley Pond, with two outlets, flows into Stony Brook in Weston.

2.3 Principal Flood Problems

Investigations into instances of flooding in Lincoln have revealed that the town has never been subjected to serious flood damage. The main flood season is spring, when melting snows combine with spring rains. However, records for the area indicate that flooding can occur in any month when the variation in monthly precipitation increases more than 10 inches for the month, when the total precipitation for a single storm exceeds 4 inches in 36 hours, or when conditions prior to a storm are conducive to flooding (Reference 5).

There have been four major floods in the SuAsCo watershed in this century: 1936, 1955, 1968, and 1979. Two floods in 1886 and 1896 were recorded as equaling the magnitude of the 1936 flood.

The flood of March, 1936 was the result of four distinct storms. The total precipitation between March 9 and March 22 ranged from 6 to 8 inches. The snow cover in the watershed had a water content at the beginning of the period which averaged approximately 3 inches. The frozen ground and the warm temperatures which accompanied the rainfall combined to give the Sudbury River one of its greatest flood peaks. Overall, property damage was minimal as the area inundated was mainly meadowland or farmland (Reference 5).

The greatest flood occurring in the watershed was the result of Hurricane Diane on August 17, 1955. Previously, on August 12, another storm, Hurricane Connie, passed over the east coast and left the ground saturated. The SuAsCo watershed received an average of 2 to 3 inches during this period. Between August 17 and 20, the area received rainfall which varied from approximately 7 inches in Lowell to more than 13 inches in the headwaters. Total rainfall averaged over 10

BEST COPY AVAILABLE

inches. The Concord River, downstream of the Sudbury River, rose slowly but continuously to flood stage, beginning on August 19 and cresting on August 23. Damage in Lincoln was relatively minor due to lack of development within the flood plain (Reference 5).

Another major storm occurred during March 1968, which is one of the wettest Marches on record. Most of the precipitation fell during two storms -- the first on March 12-13, the second on March 17-19. Snow cover in the SuAsCo watershed was above normal, with a water content up to 3 inches. Prior to the second storm, the snow had melted and saturated the wetlands surrounding the Sudbury River, producing the above normal streamflow. Combined with the unexpected heavy rainfall which began on March 17, severe flooding occurred. The peak flow of the Concord River at the U.S. Geological Survey (USGS) gaging station at Lowell (01099500) actually exceeded that of the 1955 flood. However, at the Carlisle Road bridge (State Route 225), which connects Bedford to Carlisle, the maximum flood level was 9 inches less than that experienced in 1955 References 5 and 6). The 1968 storm caused the flooding of one residence on South Great Road near Farrar Pond and caused flooding over South Great Road. This was a result of overflow by the Sudbury River. The 1968 storm was comparable to a 50-year storm or a storm having a 2 percent chance of occurence in any given year, with 4.5 inches of rain and several inches of water as snow melt (Reference 1).

The most recent flood occurred in January 1979. The month of January was an extremely wet one in eastern Massachusetts, and the accumulated precipitation set a new record of over 10 inches (Reference 7). The culmination was the storm of January 24-25 when almost 4 inches of rain fell on the SuAsCo basin (Reference 8). Although the rainfall was not a record for a single event, it came at the worst possible time. The river and upstream reservoirs were already at very high stages as a result of three one-inch storms which occurred earlier in January when the ground was frozen. Most of the rain fell on Thursday, January 25. On Friday, January 26, the Concord River downstream began to flood. The river continued to rise until it reached a peak of 9.5 feet above normal in Billerica in the early morning hours of Monday, January 29. It then began to recede slowly with a drop of approximately one foot measured on Tuesday afternoon (Reference 9).

The information below presents the relative flood heights at the Carlisle Road Bridge from Bedford to Carlisle (State Route 225) for the ten major floods in the Concord River basin, in order of magnitude.

BEST COPY AVAILABLE

Flood Heights on the Concord River (Reference 5)

Order No.	Date of Crest	Estimated Elevation**	Peak Discharge at Lowell (cfs)***
1	August 23, 1955	119.4	4,540
2	January 26, 1979*	119.3	5,400
3	March 20, 1936	119.2	6,000
4	March 27, 1968	118.7	4,900
5	July 29, 1938	118.1	3,790
6	September 15, 1954	117.5	3,340
7	Septembr 24, 1938	117.3	3,210
8	March 24, 1948	117.3	3,200
9	January 30, 1958	117.2	3,120
10	April 18, 1956	117.0	2,970

*Reference 10.

**The Carlisle Road Bridge is located 8.5 miles downstream of the Concord/Lincoln corporate limits.

***The Lowell gage is located 18.7 miles downstream of the Concord/Lincoln corporate limits.

Velocities of water during a 100-year flood on the Concord River would be approximately 2.0 feet per second (about 1.4 miles per hour) in the main channel and about 0.4 feet per second over the flood plain. During the 1936 and 1955 floods, it is estimated that velocities in the channel of the Concord River ranged up to 1.9 feet per second. Overbank velocities ranged up to 0.3 feet per second. These flood velocities are not considered hazardous (Reference 5).

The duration of flooding for most of the Concord River is generally sustained due to the large drainage area, shallow channel slopes, and wide meadow flood storage areas. Records indicate that the 1936 flood remained higher than elevation 118 at the Carlisle Road Bridge for more than eleven days. Hurricane Diane occurred on August 19 and 20, 1955, but the Concord River did not crest until late on August 22, with water levels remaining above elevation 118 for over three days (Reference 5).

BEST COPY AVAILABLE

Storms such as the one in March, 1968 could be expected to recur in the early spring when heavy rains combine with snowmelt to produce high waters. This would cause flooding on the larger rivers, where flood peaks are reached after many hours of rain. On the smaller streams in Lincoln, damage could be expected from hurricane type storms, where rain is of short duration but high intensity, causing rapid attenuation of flood peaks. This type of storm was seen in New England in August 1955, which caused extensive damage to much of the region (Reference 1).

Although Lincoln did not experience significant damage in any of the major floods, increased development and obstructions such as culverts over streams could lead to higher flood peaks and increased damages from such a flood (Reference 1).

2.4 Flood Protection Measures

There are no existing or proposed flood control structures in Lincoln. A local protection project to the south in the Saxonville section of Framingham was recently constructed along the Sudbury River. This project benefits mainly the Upper Sudbury watershed. Flood retention structures have also been constructed upstream on the Assabet River. Their effect on lowering Concord River flood elevations, however, is debatable (Reference 5).

It has been proposed that an adjustable gate be installed at the Talbot Mills Dam in North Billerica. This would allow further management of the Sudbury and Concord Rivers during heavy flooding. Low flow augmentation techniques could also be used. Opponents of the gate argue that it would conflict with other water uses and would interfere with the normal flooding cycle which is essential to wildlife along the river. It has been suggested, however, that the gate be used only when abnormal elevations are expected, and not for the normal flooding cycle (Reference 11).

Several nonstructural measures of flood protection are being utilized to aid in the prevention of future flood damage. The Lincoln Conservation Land Trust is actively involved in acquiring and preserving land in its natural state. In addition, Lincoln's Zoning Board of Appeals, under Section 12.1.2 of the zoning by-laws, may issue a special permit for encroachment within the flood plain district provided the applicant submits a report which has been approved by the Planning Board and the Board of Health indicating that the project site is not subject to flooding and not unsuitable because of drainage conditions. Additionally, Section 12.2.3.2 requires that the applicant must possess documentation from the Conservation Commission that the site is not a significant groundwater or water recharge area, not an area subject to seasonal or periodic flooding and otherwise not an area which is important for water supply (Reference 12).

BEST COPY AVAILABLE

Chapter 131, Section 40 (310 C.M.R. 10.00) of the General Laws of the Commonwealth of Massachusetts (most recently revised on April 1, 1983) is commonly referred to as the Wetlands Protection Act. The law gives the responsibility for issuing permits to remove, fill, dredge or alter wetlands to the local conservation commission. The commission has to determine if an area on which a permit is requested "is significant to public or private water supply, to the ground water supply, to flood control, to storm damage prevention, to prevention of pollution, to protection of land containing shellfish, or to the protection of fisheries." After a public hearing, the commission can impose such conditions as will contribute to the protection of these interests. The Department of Environmental Quality Engineering (DEQE) may also make a determination after a review of the commission's order. Conditions imposed by the DEQE supersede conditions imposed by the commission. Detailed rules and regulations concerning the administration of this act have been promulgated by the DEQE.

Section 40 now requires a conservation commission, if requested, to make a determination of whether a particular parcel of land is a wetland and governed by the Wetlands Protection Act. It also contains definitions of terms to aid this determination.

Chapter 131, Section 40A of the Acts of 1968, as amended by Chapter 782 of the Acts of 1972, gives the commissioner of the Department of Environmental Management the authority to protect inland wetlands and flood plains by establishing encroachment lines "for the purpose of preserving and promoting the public safety, private property, wildlife, fisheries, water resources, flood plain areas and agriculture." The commissioner may adopt orders regulating, restricting or prohibiting the altering or polluting of inland wetlands by designating lines with which no obstruction or encroachment would be permitted without prior approval. These restrictions require notifications to each land owner affected, public hearings, and approval by the town.

Section 40A was further amended by Chapter 818 by defining "inland wetlands" to include the definition of "freshwater wetlands" as set forth in Section 40, as "that portion of any bank which touches any inland waters or any freshwater wetland, and any freshwater wetland subject to flooding."

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude which are expected to be equalled or exceeded once on the average during any 10, 50, 100, or 500 year period (recurrence intervals), have been selected as having special significance for flood plain management and for flood insurance premium rates.

BEST COPY AVAILABLE

These events, commonly termed the 10, 50, 100, and 500 year floods, have a 10, 2, 1 and 0.2 percent chance, respectively, of being equalled or exceeded during any year. Although the recurrence interval represents the long term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than one year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (one percent chance of annual occurrence) in any 50 year period is about 40 percent (four in ten), and for any 90 year period, the risk increases to about 60 percent (six in ten). The analyses reported here reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge frequency relationships for floods of the selected recurrence intervals for each flooding source studied in detail in the community.

Discharge frequency estimates for the Sudbury River were established during the preparation of the Flood Insurance Study for the Town of Concord (Reference 13). The peak discharge frequency relationship for the Sudbury River was established by modifying the Log Pearson Type III statistical analysis of the annual peak discharge data for the Sudbury River at Framingham. Natural river flows were then modified to reflect the change in peak flow caused by the intervening drainage area. Because these studies are authoritative for purposes of the National Flood Insurance Program, these estimates were incorporated into this study.

Because no gaging data were available for the smaller streams in Lincoln, peak discharge frequency estimates for the 10-, 50-, and 100-year floods on Farrar Pond/Pole Brook, Farrar Pond Brook, Hobbs Brook, Stony Brook, and Valley Pond were determined using the USGS regional method (Reference 14). The 500-year peak discharge estimates for these streams were determined by using a straight line extrapolation of plotted flood discharges for frequencies up to 100 years on log-probability paper.

Although Todd Pond Brook was not studied in detail, the 100-year peak discharge was calculated using the USGS regional method (Reference 14). The drainage area at the outlet of Todd Pond is approximately 0.8 square miles, and the 100-year peak discharge is approximately 68 cubic feet per second (cfs).

BEST COPY AVAILABLE

A summary of drainage area - peak discharge relationships for each stream studied in detail is shown in Table 1.

Table 1 - Summary of Discharges

Flooding Source and Location	Drainage Area Sq. Mi.	Peak Discharges (cfs) 10 Yr.	50 Yr.	100 Yr.	500 Yr.
SUDBURY RIVER					
At Fairhaven Bay Outlet	158.40	1770	2800	3340	4930
FARRAR POND BROOK					
At mouth	1.06	51	75	85	110
POLE BROOK/FARRAR POND					
At Sudbury River Junction	2.19	100	147	169	237
At mouth of Pole Brook	1.04	54	80	92	129
At Concord Road	0.54	38	57	65	91
HOBBS BROOK					
At Lexington Road	2.35	97	145	167	221
STONY BROOK					
At confluence with Iron Mine Brook	2.30	95	144	167	230
At Tower Road	1.20	54	82	95	131
At Brooks School	1.00	45	68	79	96
VALLEY POND					
At Valley Pond Outlet	1.78	77	116	133	185

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of the flooding sections studied in detail in Lincoln were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along each of the flood sources.

Cross sections for backwater analyses of the study streams were field surveyed and spaced at specific intervals along the river channel in order that hydraulic properties would be accurately modeled by the computer. Sections were interpolated between surveyed sections where necessary. These interpolated sections were prepared from survey data and data from topographic maps (Reference 15).

The below-water sections were obtained by field measurement. All bridges, dams, and culverts were field checked to obtain elevation data and structural geometry.

BEST COPY AVAILABLE

Locations of selected cross sections used in hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the Flood Boundary and Floodway Map.

Channel roughness factors (Manning's "n") used in the hydraulic computations were chosen by engineering judgment and based on field observations of the streams and flood plain areas and are as follows:

Stream	Manning's "n" Value	
	Channel	Overbank
Sudbury River	0.050	0.100
Farrar Pond Brook	0.045 to 0.075	0.050
Pole Brook/Farrar Pond	0.020 to 0.060	0.090 to 1.100
Hobbs Brook	0.045 to 0.075	0.045 to 0.075
Stony Brook	0.045	0.050

Roughness values for Valley Pond were not determined. Water surface elevations for the pond were calculated on the ability of the spillway to pass a flow having a specific return frequency.

The acceptability of all assumed hydraulic factors, cross sections and hydraulic structure data for the Sudbury River was checked by computations that duplicated historic flood water profiles.

Water surface elevations of floods of the selected recurrence intervals were computed through use of the COE HEC-2 step-backwater computer program (Reference 16). Flood profiles were drawn showing computed water surface elevations for floods of the selected recurrence intervals. All elevations are referenced from the National Geodetic Vertical Datum of 1929 (NGVD), formerly referred to as the Sea Level Datum of 1929; elevation reference marks used in this study are shown on the maps.

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

4.0 FLOOD PLAIN MANAGEMENT APPLICATIONS

The National Flood Insurance Program encourages state and local governments to adopt sound flood plain management programs. Therefore, each Flood Insurance Study includes a flood boundary map designed to assist communities in developing sound flood plain management measures.

BEST COPY AVAILABLE

4.1 Flood Boundaries

In order to provide a national standard without regional discrimination, the 100-year flood has been adopted by the FEMA as the base flood for purposes of flood plain management measures. The 500-year flood is employed to indicate additional areas of flood risk in the community. For each stream studied in detail, the boundaries of the 100- and the 500-year floods have been delineated using the flood elevations determined at each cross section; between cross sections, the boundaries were interpolated using photogrammetric maps at a scale of 1:4,800 with a contour interval of 5 feet (Reference 2). In cases where the 100-and the 500-year flood boundaries are close together, only the 100-year boundary has been shown.

For the streams studied by approximate methods, the boundaries of the 100-year flood were developed from normal depth calculations and the photogrammetric maps referenced above.

The boundaries of the 100- and 500-year floods are shown on the Flood Boundary and Floodway Map. Small areas within the flood boundaries may lie above the flood elevations, and therefore, may not be subject to flooding. Owing to limitations of the map scale and/or lack of detailed topographic data, such areas are not shown.

4.2 Floodways

Encroachment on flood plains, such as artificial fill, reduces the flood-carrying capacity, increases the flood heights of streams, and increases flood hazards in areas beyond the encroachment itself. One aspect of flood plain management involves balancing the economic gain from flood plain development against the resulting increase in flood hazard. For purposes of the National Flood Insurance Program, the concept of a floodway is used as a tool to assist local communities in this aspect of flood plain management. Under this concept, the area of the 100-year flood is divided into a floodway and a floodway fringe. The floodway is the channel of a stream plus any adjacent flood plain areas that must be kept free of encroachment in order that the 100-year flood can be carried without substantial increases in flood heights. Minimum standards of the FEMA limit such increases in flood heights to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this report are presented to local agencies as a minimum standard that can be adopted or that can be used as a basis for additional studies.

The floodways for this study were computed on the basis of equal conveyance reduction from each side of the flood plain. The results of these computations were tabulated at selected cross sections for each stream segment for which a floodway was computed (Table 2).

BEST COPY AVAILABLE

BEST COPY AVAILABLE

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
					(FEET NGVD)			
SUDBURY RIVER								
A	1,365 [1]	1,700/860 [3]	26,660	0.1	121.7	121.7	122.6	0.9
B	2,715 [1]	1,200/250 [3]	13,650	0.2	121.7	121.7	122.6	0.9
C	4,800 [1]	460/370 [3]	5,180	0.6	121.7	121.7	122.6	0.9
D	6,055 [1]	100/ 15 [3]	1,985	0.7	121.9	121.9	122.9	1.0
FARRAR POND BROOK								
A	200 [2]	20	72	1.2	122.0	122.0 [4]	123.0	1.0
B	455 [2]	13	77	1.1	125.0	125.0	125.0	0.0
C	625 [2]	5	19	4.5	125.0	125.0	125.0	0.0
D	880 [2]	7	34	2.5	129.3	129.3	129.5	0.2
E	1,150 [2]	6	32	2.6	129.3	129.3	130.1	0.8
F	1,975 [2]	30	107	0.8	138.1	138.1	138.1	0.0
G	2,300 [2]	20	68	1.2	143.5	143.5	143.5	0.0
H	2,645 [2]	4	10	8.5	164.1	164.1	164.1	0.0

1 Feet Above Corporate Limits
2 Feet Above Confluence with Farrar Pond
3 Width/Width within Corporate Limits
4 Water Surface Elevation without considering Backwater Effects from Farrar Pond

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA
(MIDDLESEX COUNTY)

FLOODWAY DATA

SUDBURY RIVER AND FARRAR POND BROOK

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
					(FEET NGVD)			
FARRAR POND/ POLE BROOK								
A	375[1]	210	1,960	0.1	122.0	122.0[3]	123.0	1.0
B	5,380[1]	20	21	4.3	134.1	134.1	134.3	0.2
C	5,875[1]	4	8	8.2	148.3	148.3	148.3	0.0
D	6,220[1]	20	86	0.8	157.6	157.6	157.6	0.0
E	6,595[1]	20	41	1.6	160.5	160.5	160.8	0.3
F	6,865[1]	20	37	1.8	161.3	161.3	162.2	0.9
G	7,170[1]	40	78	0.8	161.9	161.9	162.8	0.9
H	8,530[1]	20	41	1.6	163.2	163.2	164.0	0.8
HOBBS BROOK								
A	160[2]	67	410	0.4	173.4	173.4	174.4	1.0
B	760[2]	79	232	0.7	174.2	174.2	175.2	1.0
C	1,660[2]	21	25	6.3	177.2	177.2	177.2	0.0

1 Feet Above Confluence with Sudbury River
2 Feet Above Corporate Limits
3 Water - Surface Elevation without considering Backwater Effects from Sudbury River

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA
(MIDDLESEX COUNTY)

FLOODWAY DATA

FARRAR POND/POLE BROOK AND HOBBS BROOK

BEST COPY AVAILABLE

BEST COPY AVAILABLE

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
					(FEET NGVD)			
STONY BROOK								
A	6,930	25	78	2.1	170.4	170.4	171.4	1.0
B	7,190	20	46	3.6	176.4	176.4	176.4	0.0
C	8,095	20	18	5.4	181.1	181.1	181.1	0.0
D	8,840	39	36	2.7	191.8	191.8	191.8	0.0
E	9,160	21	45	2.1	202.7	202.7	203.0	0.3
F	9,790	12	36	2.6	207.3	207.3	207.5	0.2
G	9,990	18	41	2.3	207.8	207.8	208.0	0.2
H	10,775	24	37	2.5	213.5	213.5	213.5	0.0
I	10,940	26	87	1.1	216.6	216.6	216.6	0.0
J	11,570	14	45	2.1	217.3	217.3	217.3	0.0
K	11,910	16	30	2.6	217.9	217.9	217.9	0.0
L	12,330	23	57	1.4	218.5	218.5	218.5	0.0
M	12,960	20	48	1.7	219.4	219.4	220.1	0.7
N	13,820	10	27	2.9	228.6	228.6	229.6	1.0
O	14,020	6	14	5.6	230.2	230.2	230.8	0.6
P	14,400	18	15	5.2	236.5	236.5	236.5	0.0

1 Feet Above Corporate Limits

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

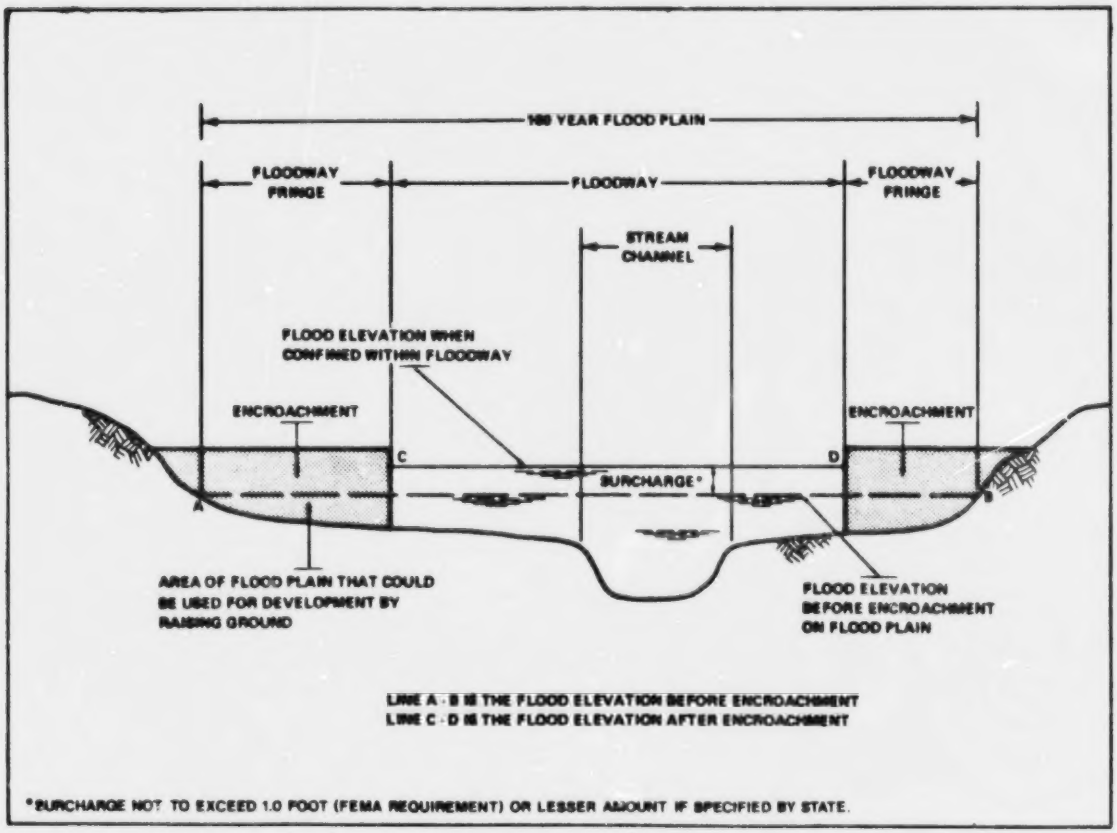
TOWN OF LINCOLN, MA
(MIDDLESEX COUNTY)

FLOODWAY DATA

STONY BROOK

As shown on the Flood Boundary and Floodway Map, the floodway widths were determined at cross sections; between cross sections, the boundaries were interpolated. In cases where the boundaries of the floodway and the 100-year flood are either close together or collinear, only the floodway boundary has been shown.

The area between the floodway and the boundary of the 100-year flood is termed the floodway fringe. The floodway fringe thus encompasses the portion of the flood plain that could be completely obstructed without increasing the water surface elevation of the 100-year flood more than 1.0 foot at any point. This allowable increase considers only the hydraulic response of the stream and its flood plain to any encroachment. The increase in the water-surface elevation is a result of the 100-year flood discharge flowing through a smaller flood plain area. Typical relationships between the floodway and the floodway fringe and their significance to flood plain development are shown in Figure 2.


100 YEAR FLOOD PLAIN
FLOODWAY FRINGE
FLOODWAY
FLOODWAY FRINGE
STREAM CHANNEL
FLOOD ELEVATION WHEN CONFINED WITHIN FLOODWAY
ENCROACHMENT
ENCROACHMENT
C
D
SURCHARGE*
A
B
AREA OF FLOOD PLAIN THAT COULD BE USED FOR DEVELOPMENT BY RAISING GROUND
FLOOD ELEVATION BEFORE ENCROACHMENT ON FLOOD PLAIN
LINE A - B IS THE FLOOD ELEVATION BEFORE ENCROACHMENT
LINE C - D IS THE FLOOD ELEVATION AFTER ENCROACHMENT
*SURCHARGE NOT TO EXCEED 1.0 FOOT (FEMA REQUIREMENT) OR LESSER AMOUNT IF SPECIFIED BY STATE.

FLOODWAY SCHEMATIC **Figure 2**

BEST COPY AVAILABLE

One aspect of floodway and flood plain encroachment is sometimes overlooked and more often neglected: the cumulative effect of encroachment on flood discharge magnitude. Generally, as encroachment occurs, temporary storage areas are lost, velocities increase, and the magnitude of the discharge increases. As floodwaters move downstream, that increase can become more significant. The combined effect of a narrower flood plain and greater discharge can, due to hydraulic effects alone, produce a flood stage that exceeds the anticipated 100-year flood.

The FEMA does not encourage the filling of the floodway fringe area. Local officials should be aware that even a one-foot rise in the water-surface elevation can cause flooding in areas which would have received little or no flooding if such filling had not taken place. Careful consideration of the economic and human dislocation which will be caused by a rise in flood heights should be made before filling is allowed. Large quantities of fill in the fringe area could also disrupt the flood plain ecosystem, causing a major impact on local environmental resources.

Communities are encouraged by the FEMA to adopt wider, more restrictive floodways and to minimize the amount of fill allowed in the fringe areas. Such actions also meet the intent of the Massachusetts Wetlands Protection Act (Massachusetts General Laws, Chapter 131, Section 40), which was previously described in Section 2.4.

In order to achieve a unified flood plain and wetlands management program, numerous Massachusetts communities have adopted local zoning by-laws, ordinances, subdivision regulations, and local board of health regulations augmenting the minimum requirements of the National Flood Insurance Program and the Massachusetts Wetlands Protection Act. The FEMA encourages the use of this Flood Insurance Study as the technical basis for adoption of a broader, more encompassing local flood plain management program than is required to meet the minimum standards of the National Flood Insurance Program.

5.0 INSURANCE APPLICATION

In order to establish actuarial insurance rates, the FEMA has developed a process to transform the data from the engineering study into flood insurance criteria. This process includes the determination of reaches, Flood Hazard Factors (FHFs), and flood insurance zone designations for each significant flooding source affecting the town of Lincoln.

5.1 Reach Determinations

Reaches are defined as lengths of watercourses having relatively the same flood hazard, based on the average weighted difference in water surface elevations between the 10- and

BEST COPY AVAILABLE

100-year floods. This difference does not have a variation greater than that indicated in the following table for more than 20 percent of the reach.

Average Difference Between 10- and 100-Year Floods	Variation
Less than 2 feet	0.5 foot
2 to 7 feet	1.0 foot

Eight reaches meeting the above criteria were required for the flooding sources of Lincoln. These include one each on the Sudbury River, Farrar Pond Brook, Stony Brook and Valley Pond and two each on Farrar Pond/Pole Brook and Hobbs Brook. The locations of the reaches are shown on the Flood Profiles.

5.2 Flood Hazard Factors (FHFs)

The Flood Hazard Factor is used to correlate flood information with insurance rate tables. Correlations between property damages from floods and their assigned FHFs are used to set actuarial insurance premium rate tables based on FHFs from 005 to 200.

The FHF for a reach is the average weighted difference between the 10- and 100-year flood water surface elevations expressed to the nearest one-half foot, and shown as a three-digit code. For example, if the difference between the water surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year flood water surface elevations is greater than 10.0 feet, the accuracy for the FHF is to the nearest foot.

5.3 Flood Insurance Zones

After the determination of reaches and their respective FHFs, the entire incorporated area of Billerica was divided into zones, each having a specific flood potential or hazard. Each zone was assigned one of the following flood insurance zone designations:

Zone A:	Special Flood Hazard Areas inundated by the 100-year flood, determined by approximate methods, no base flood elevations shown or FHFs determined.
Zones A1, A2, A6, A8:	Special Flood Harzard Areas inundated by the 100-year flood, determined by detailed methods; base flood elevations shown, and zones assigned according to FHFs.

BEST COPY AVAILABLE

Zone B: Areas between the Special Flood Hazard Areas and the limits of the 500-year flood, including areas of the 500-year flood plain that are protected from the 100-year flood by dike, levee, or other water control structure; areas subject to certain types of 100-year shallow flooding where depths are less than 1.0 foot; or, areas subject to 100-year flooding from sources with drainage areas of less than one square mile. Zone B is not subdivided.

Zone C: Areas of minimal flooding.

Table 3, "Flood Insurance Zone Data," summarizes the flood elevation differences, FHFs, flood insurance zones, and base flood elevations for each source studied in detail in the community.

5.4 Flood Insurance Rate Map Description

The Flood Insurance Rate Map for the town of Lincoln is, for insurance purposes, the principal result of the Flood Insurance Study. This map (published separately) contains the official delineation of flood insurance zones and base flood elevation lines. Base flood elevation lines show the locations of the expected whole-foot water surface elevations of the base (100-year) flood. This map is developed in accordance with the latest flood insurance map preparation guidelines published by the FEMA.

6.0 OTHER STUDIES

The communities adjoining Lincoln are the city of Waltham, and the Towns of Weston, Wayland, Concord, Bedford and Lexington. The Flood Insurance Studies for Waltham, Concord, and Bedford agree with this study at their respective corporate limits (Reference 17, 13, and 18). Discrepancies exist at the corporate limits between Lincoln and Wayland, Lincoln and Weston, and Lincoln and Lexington (References 19, 20, and 21). This study is based upon more accurate information and should be considered to be valid.

Discrepancies exist between the Flood Boundary and Floodway Maps (Exhibit 3) of the streams studied in detail and the Floodway Data Table (Table 2), the Flood Profiles (Exhibit 1) and the Flood Insurance Rate Maps. These discrepancies are considered to be minor and result from more accurate mapping being utilized in this study.

This study is authoritative for purposes of the Flood Insurance Program, and the data presented here either supersede or are compatible with previous determinations.

BEST COPY AVAILABLE

BLANK PAGE

BLANK PAGE

BLANK PAGE

FLOODING SOURCE	PANEL[1]	ELEVATION DIFFERENCE[2] BETWEEN 1% (100-YEAR) FLOOD AND			FLOOD HAZARD FACTOR	ZONE	BASE FLOOD ELEVATION (FEET NGVD)[3]
		10% (10-YEAR)	2% (50-YEAR)	0.2% (500-YEAR)			
SUDBURY RIVER							
Reach 1	10	-4.0	-1.4	3.3	040	A8	122
FARRAR POND BROOK							
Reach 1	10	-0.5	-0.1	0.4	005	A1	varies
FARRAR POND/POLE BROOK							
Reach 1	10	-2.9	-1.5	3.4	030	A6	varies
Reach 2	10	-0.4	-0.1	0.3	005	A1	varies
HOBBS BROOK							
Reach 1	05,10	-1.2	-0.5	0.9	010	A2	varies
Reach 2	05	-0.4	-0.1	0.6	005	A1	varies
STONY BROOK							
Reach 1	10	-0.7	-0.2	0.3	005	A1	varies
VALLEY POND							
Reach 1	10	-0.2	-0.1	0.1	005	A1	177

[1]Flood Insurance Rate Map Panel [2]Weighted Average [3]Rounded to Nearest Foot - see map

TABLE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA
(MIDDLESEX COUNTY)

FLOOD INSURANCE ZONE DATA

SUDBURY RIVER, FARRAR POND BROOK, FARRAR POND/POLE BROOK, HOBBS BROOK, STONY BROOK AND VALLEY POND

BEST COPY AVAILABLE

7.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this study can be obtained by contacting the Natural and Technological Hazards Division, Federal Emergency Management Agency, Region I Office, John W. McCormack Post Office and Courthouse Building, Post Office Square, Boston, Massachusetts 02109.

8.0 BIBLIOGRAPHY AND REFERENCES

1. Federal Emergency Management Agency, Flood Insurance Study, Town of Lincoln, Middlesex County, Massachusetts, Washington, D.C., December 1977.

2. Aerial Photography, American Air Surveys, Inc., Pittsburgh, Pennsylvania, Scale: 1:2,400, Contour Interval 5 Feet, December 1968.

3. U.S. Department of Commerce, Bureau of the Census, 1980 Census of Population and Housing (Preliminary Reports), Washington, D.C. November 1980.

4. Commonwealth of Massachusetts, Department of Commerce and Development, Massachusetts Community Data, Lincoln, Middlesex County, Boston, Massachusetts, March 1979.

5. U.S. Department of the Army, Corps of Engineers, New England Division, Flood Plain Information Report, Concord and Shawsheen Rivers, Bedford, Massachusetts, Waltham, Massachusetts, September 1968.

6. U.S. Department of Interior, Geological Survey, Flood of March 1968 in Eastern Massachusetts and Rhode Island, Boston, Massachusetts, 1970.

7. Boston Herald-American, "January Set a New Record," Boston, Massachusetts, January 26, 1979.

8. Boston Globe, Various Articles, Boston, Massachusetts, January 28 and 29, 1979.

9. Billerica Minute-Man, Various Articles, Billerica, Massachusetts, January 31, February 1 and 8, 1979.

10. U.S. Army, Corps of Engineers, New England Division, Identification and Location of High Water Marks - Flood of January, 1979, Six Rivers in Southern New England, Waltham, Massachusetts, 1979.

11. Commonwealth of Massachusetts, Metropolitan District Commission, A Study of the Upper Sudbury River Watershed, Boston, Massachusetts, 1979 (amended).

BEST COPY AVAILABLE

12. Town of Lincoln, Massachusetts, Zoning By-Laws, Amended March 24, 1979.

13. Federal Emergency Management Agency, Flood Insurance Study, Town of Concord, Middlesex County, Massachusetts, Washington, D.C. (latest version in progress).

14. U.S. Department of the Interior, Geological Survey, Open-File Report Number 74-131, Flood Magnitude and Frequency of Massachusetts Streams, Boston, Massachusetts, March 1974.

15. U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, Technical Release No. 55 (TR-55), Urban Hydrology for Small Watersheds, Washington, D.C., January 1975.

16. U.S. Army, Corps of Engineers, Hydrologic Engineering Center, Computer Program 723-X6-L202A, HEC-2 Water Surface Profiles, Davis, California, December 1968, with updates.

17. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, City of Waltham, Middlesex County, Massachusetts, Washington, D.C., June 1979.

18. Federal Emergency Management Agency, Flood Insurance Study, Town of Bedford, Middlesex County, Massachusetts, Washington, D.C., (latest version in progress).

19. Federal Emergency Management Agency, Flood Insurance Study, Town of Wayland, Middlesex County, Massachusetts, Washington, D.C., December 1981.

20. Federal Emergency Management Agency, Flood Insurance Study, Town of Weston, Middlesex County, Massachusetts, Washington, D.C., January 1980.

21. U.S. Department of Housing and Urban Development, Federal Insurance Administration, Flood Insurance Study, Town of Lexington, Middlesex County, Massachusetts, Washington, D.C., December 1977.

Chow, Ven T., Handbook of Applied Hydrology, McGraw-Hill Book Company, New York, N.Y., 1964.

Chow, Ven T., Open-Channel Hydraulics, McGraw-Hill Book Company, New York, N.Y., 1959.

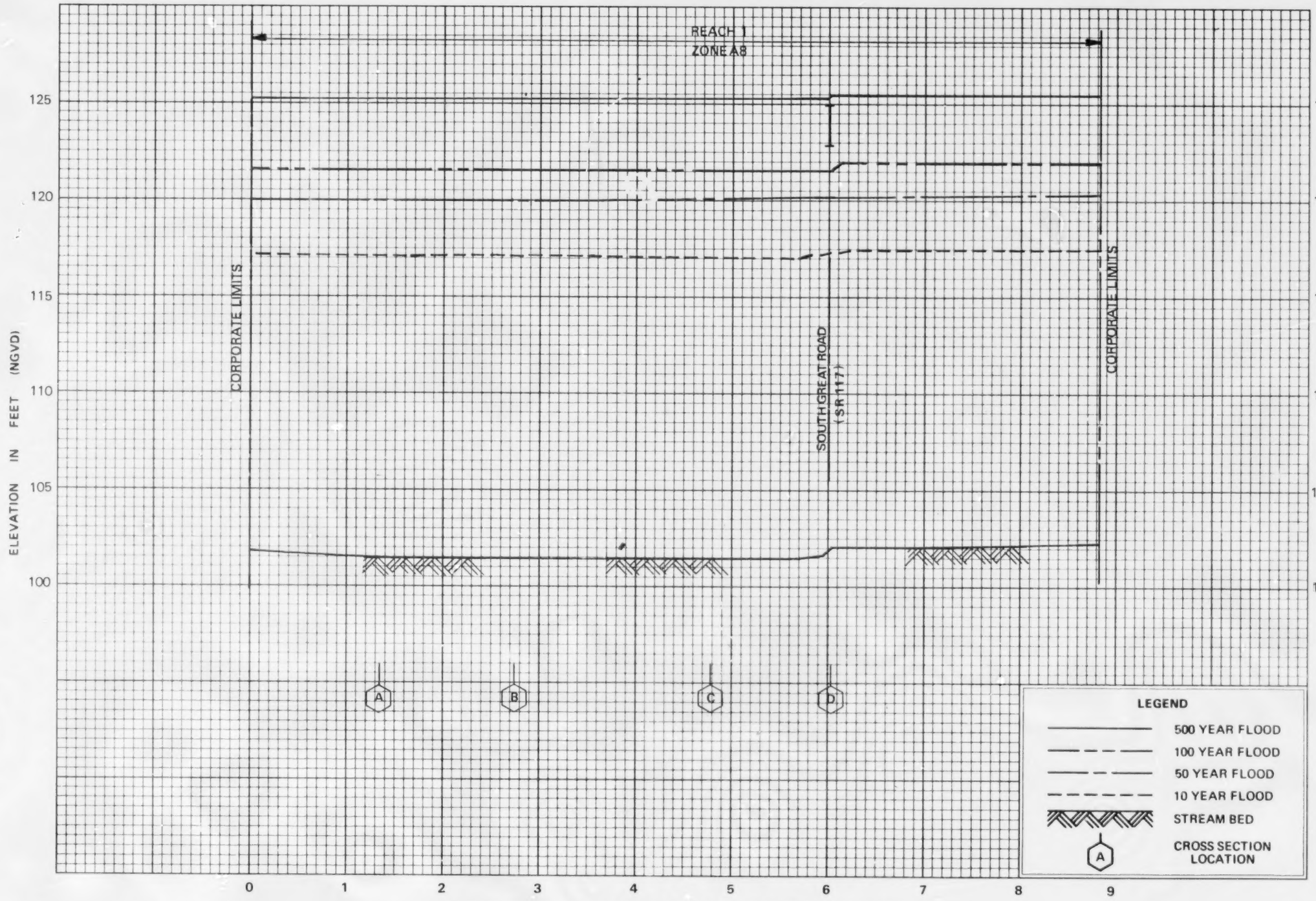
King, H.W., and Brater, E.F., Handbook of Hydraulics, 6th Edition, McGraw-Hill Book Company, New York, N.Y., 1976.

BEST COPY AVAILABLE

U.S. Department of the Interior, Geological Survey, Runoff Coefficients of Natural Channels, Water Supply Paper 1849, Washington, D.C., 1967.

U.S. Department of the Interior, Geological Survey, 7.5-Minute Series Topographics Maps, Scale 1:24,000, Contour Interval 10 feet: Billerica, Massachusetts (1965), Wilmington, Massachusetts (1965).

BEST COPY AVAILABLE



FLOOD PROFILES

SUDBURY RIVER

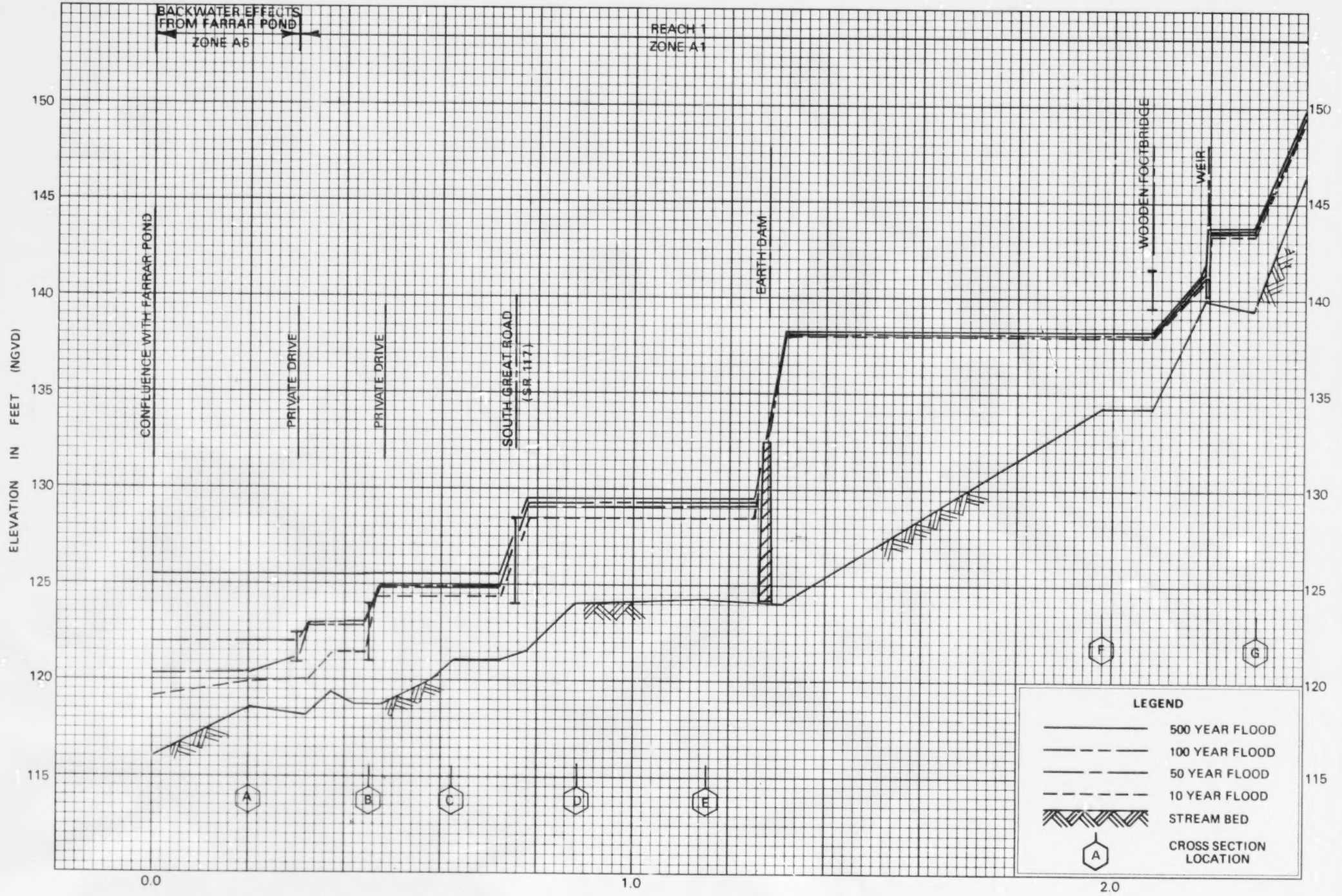
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

MIDDLESEX COUNTY

01P

BEST COPY AVAILABLE



FLOOD PROFILES

FARRAR POND BROOK

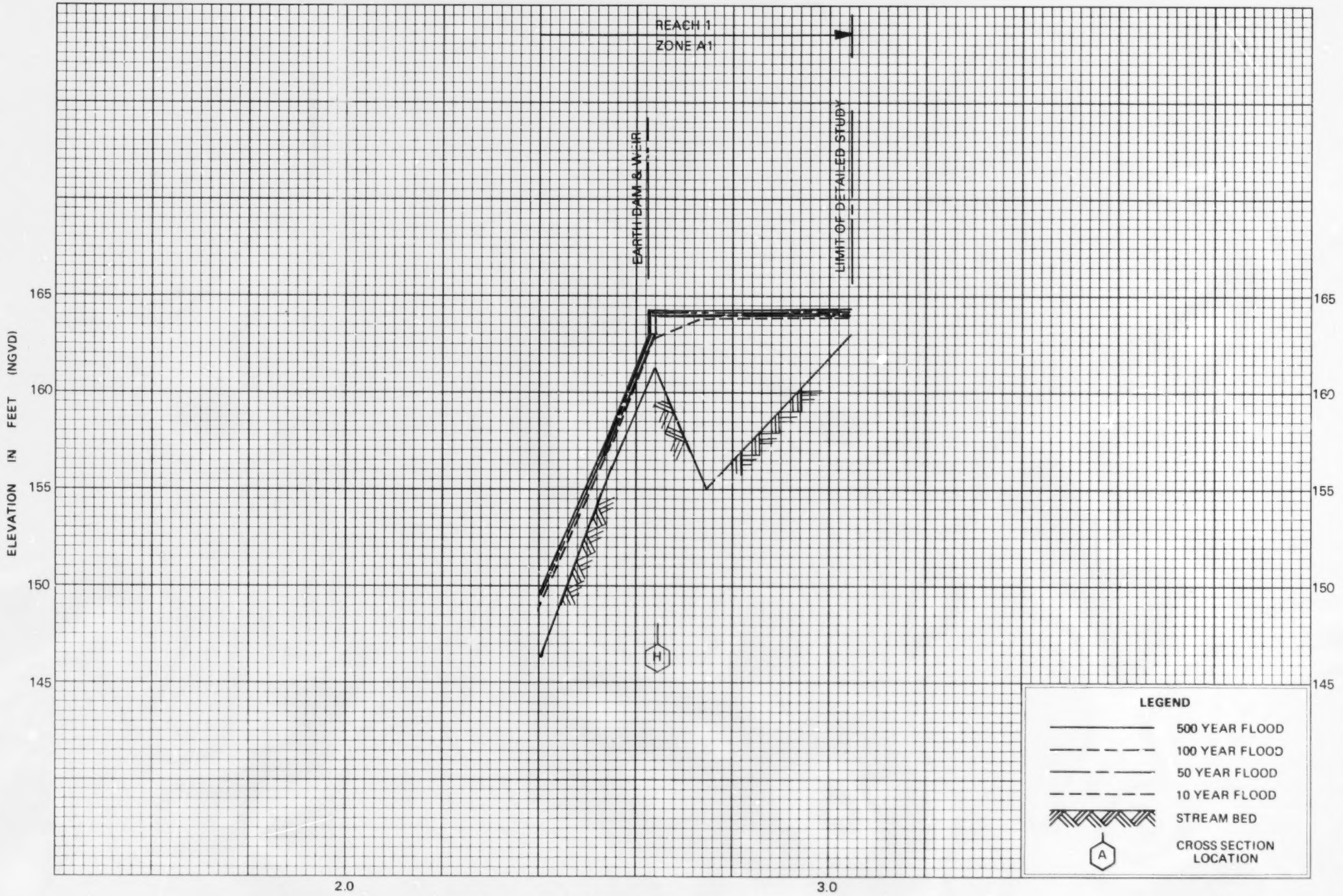
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

02P

BEST COPY AVAILABLE



FLOOD PROFILES

FARRAR POND BROOK

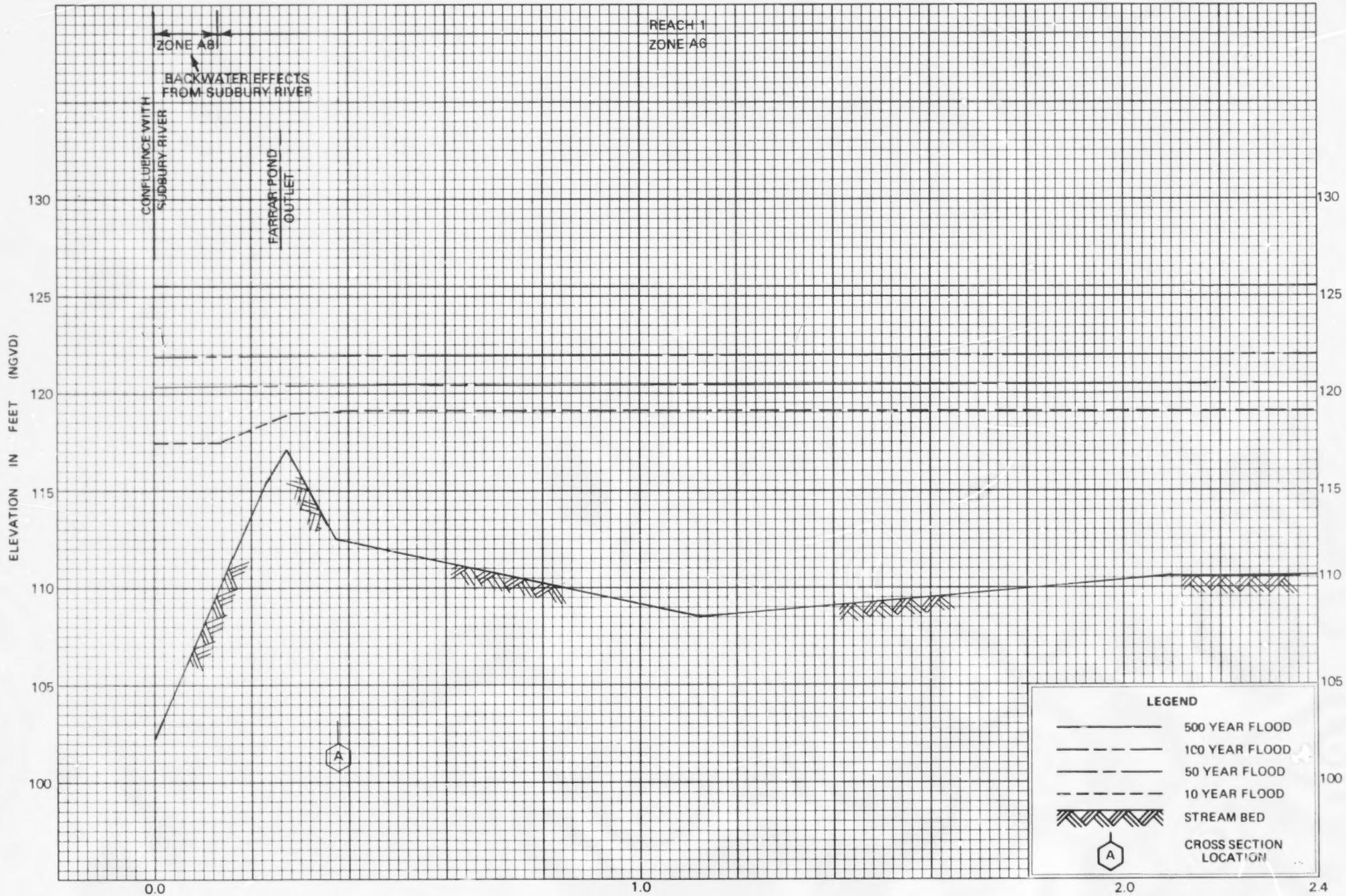
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

03P

BEST COPY AVAILABLE



FLOOD PROFILES

FARRAR POND / POLE BROOK

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

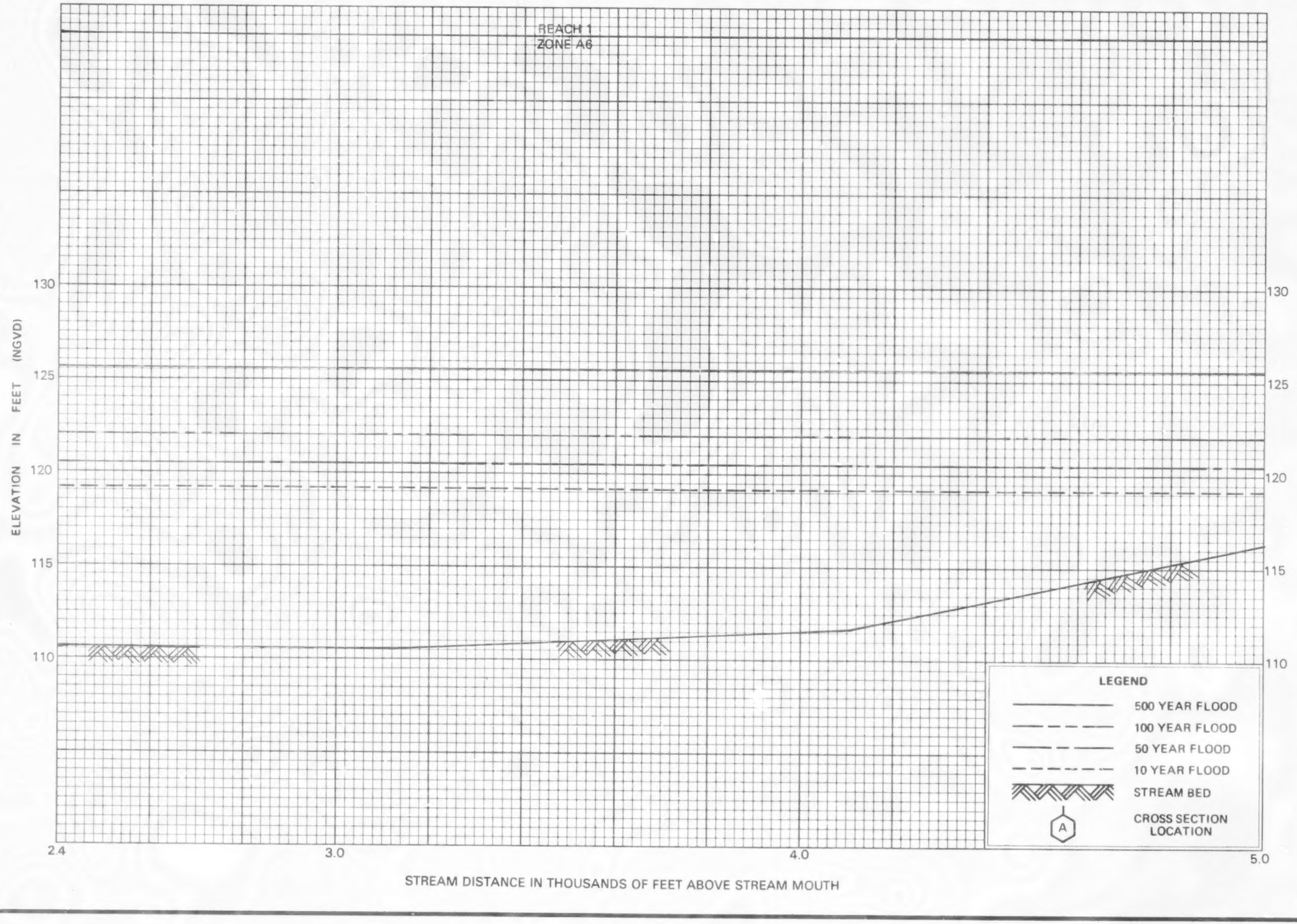
04P

BEST COPY AVAILABLE

BLANK PAGE

BLANK PAGE

BLANK PAGE



FLOOD PROFILES

FARRAR POND / POLE BROOK

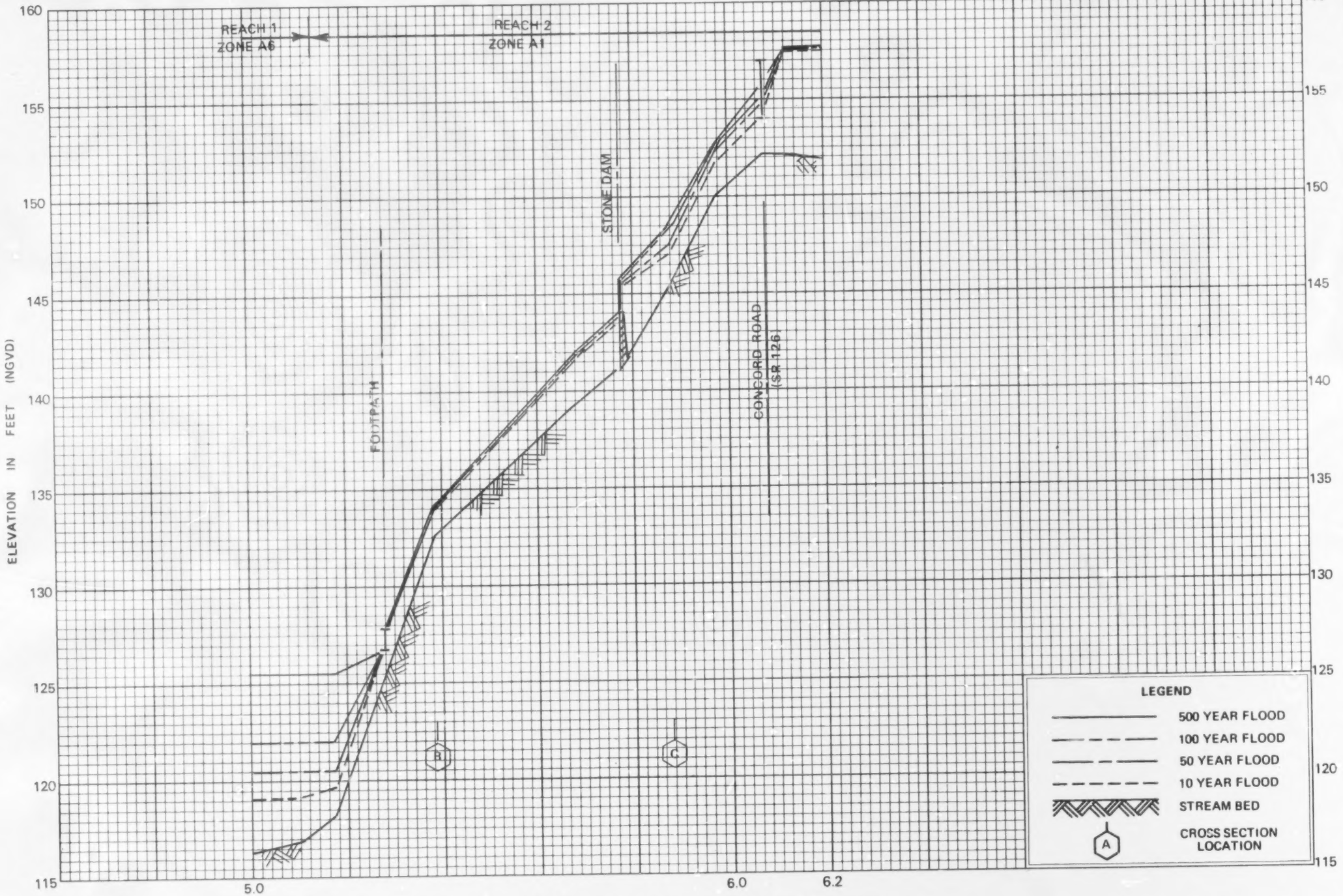
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

05P

BEST COPY AVAILABLE



STREAM DISTANCE IN THOUSANDS OF FEET ABOVE STREAM MOUTH

FLOOD PROFILES

FARRAR POND / POLE BROOK

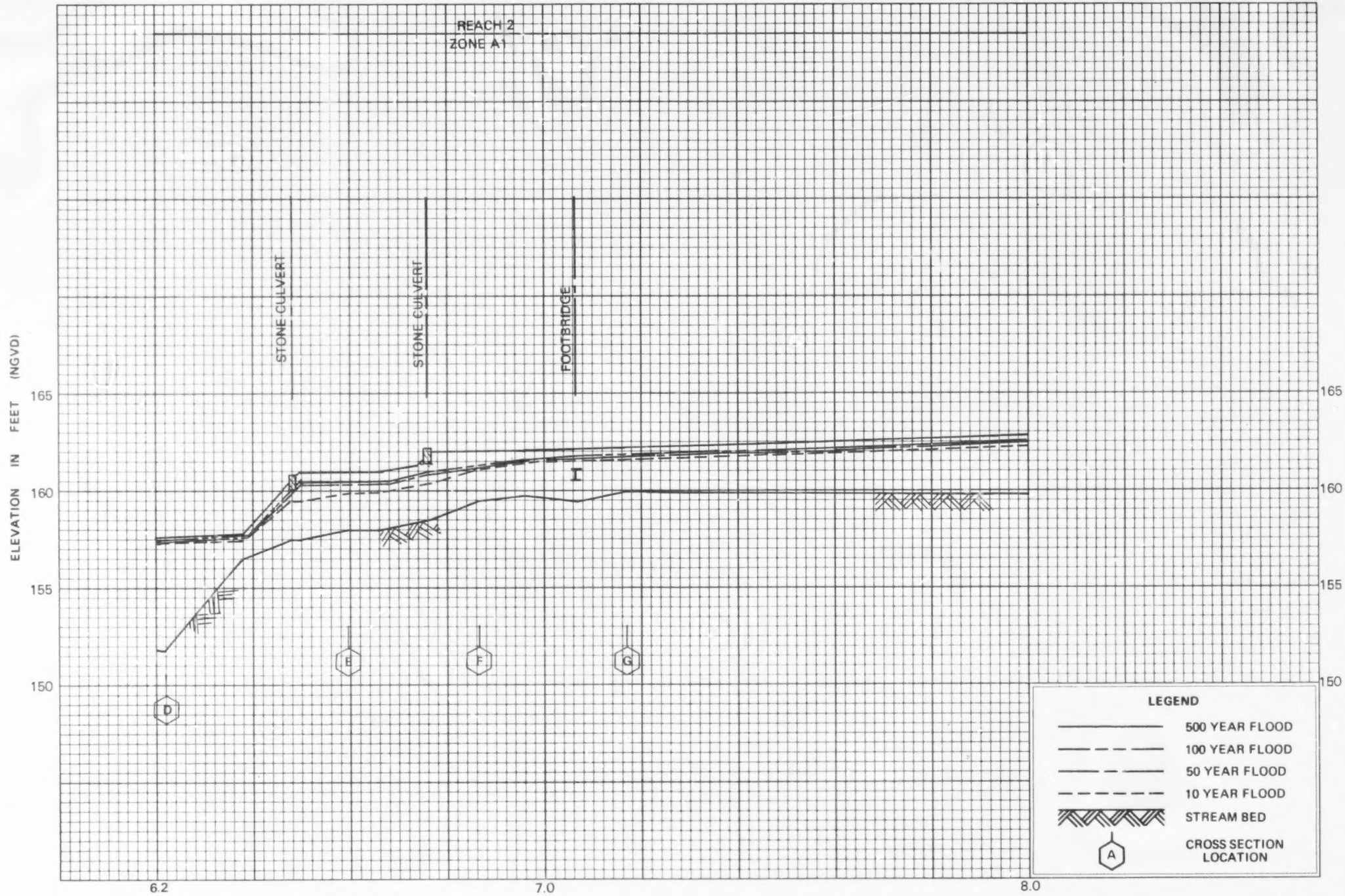
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

06P

BEST COPY AVAILABLE



FLOOD PROFILES

FARRAR POND / POLE BROOK

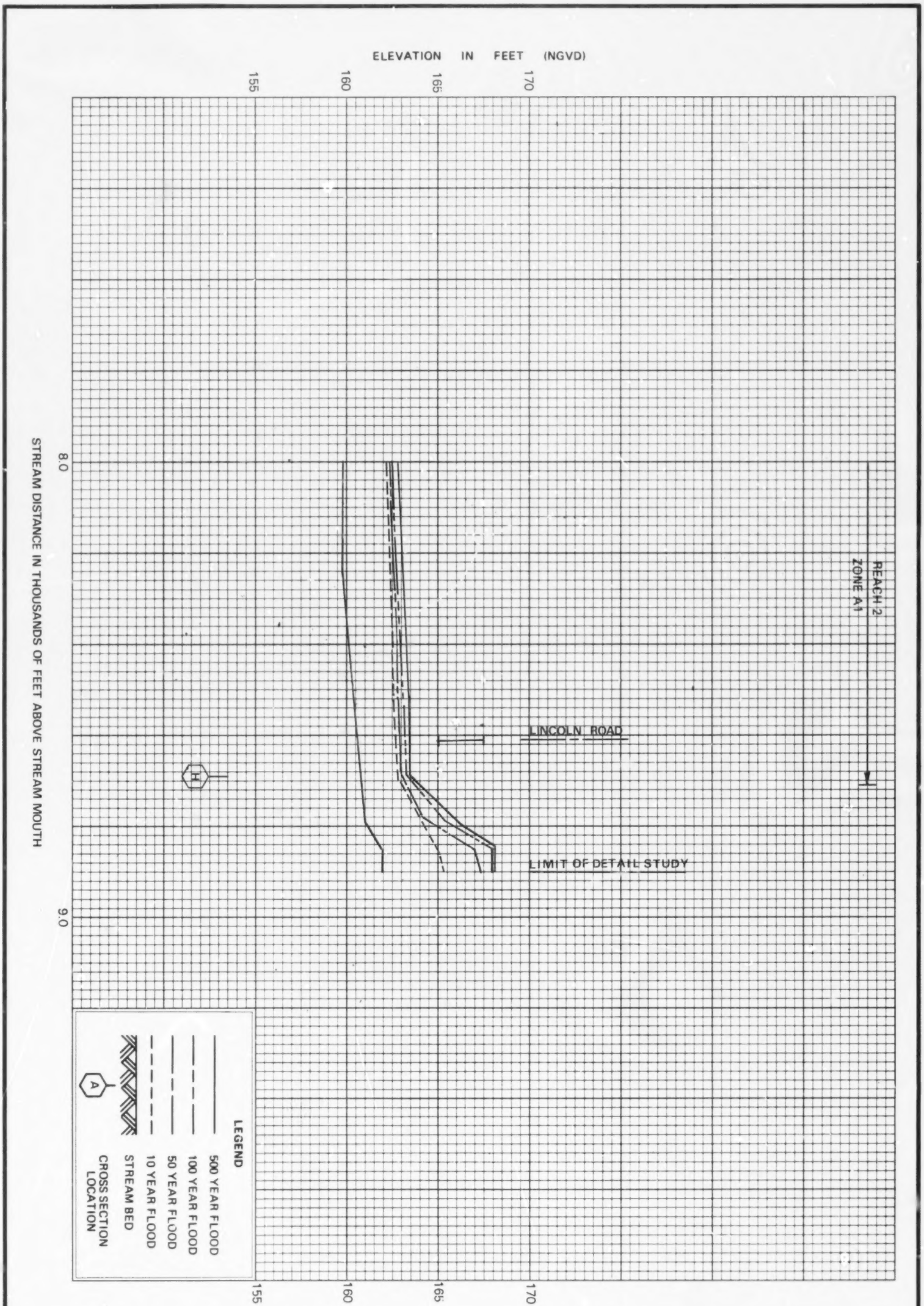
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

07P

BEST COPY AVAILABLE



FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

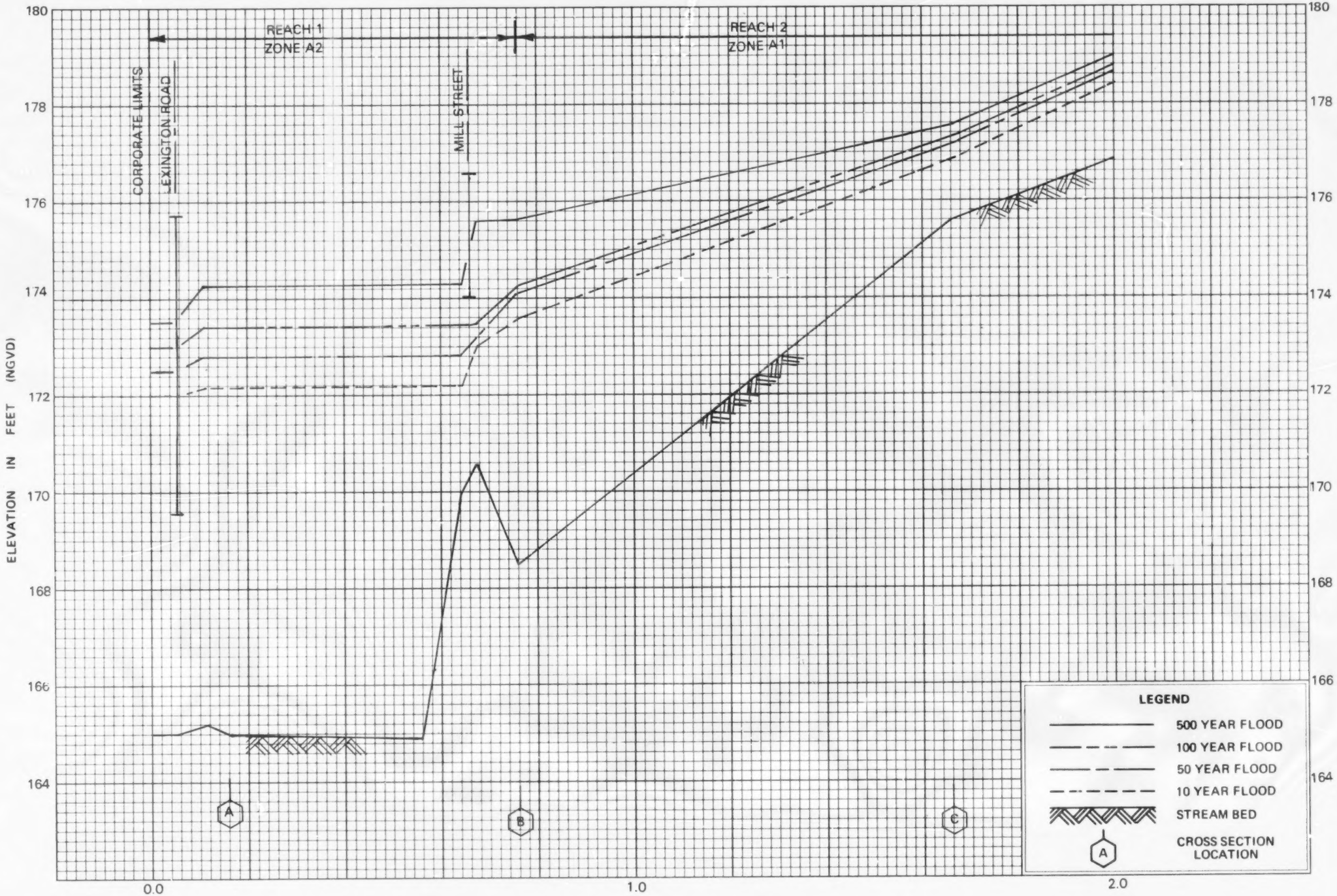
(MIDDLESEX COUNTY)

08P

FLOOD PROFILES

FARRAR POND / POLE BROOK

BEST COPY AVAILABLE



FLOOD PROFILES

HOBBS BROOK

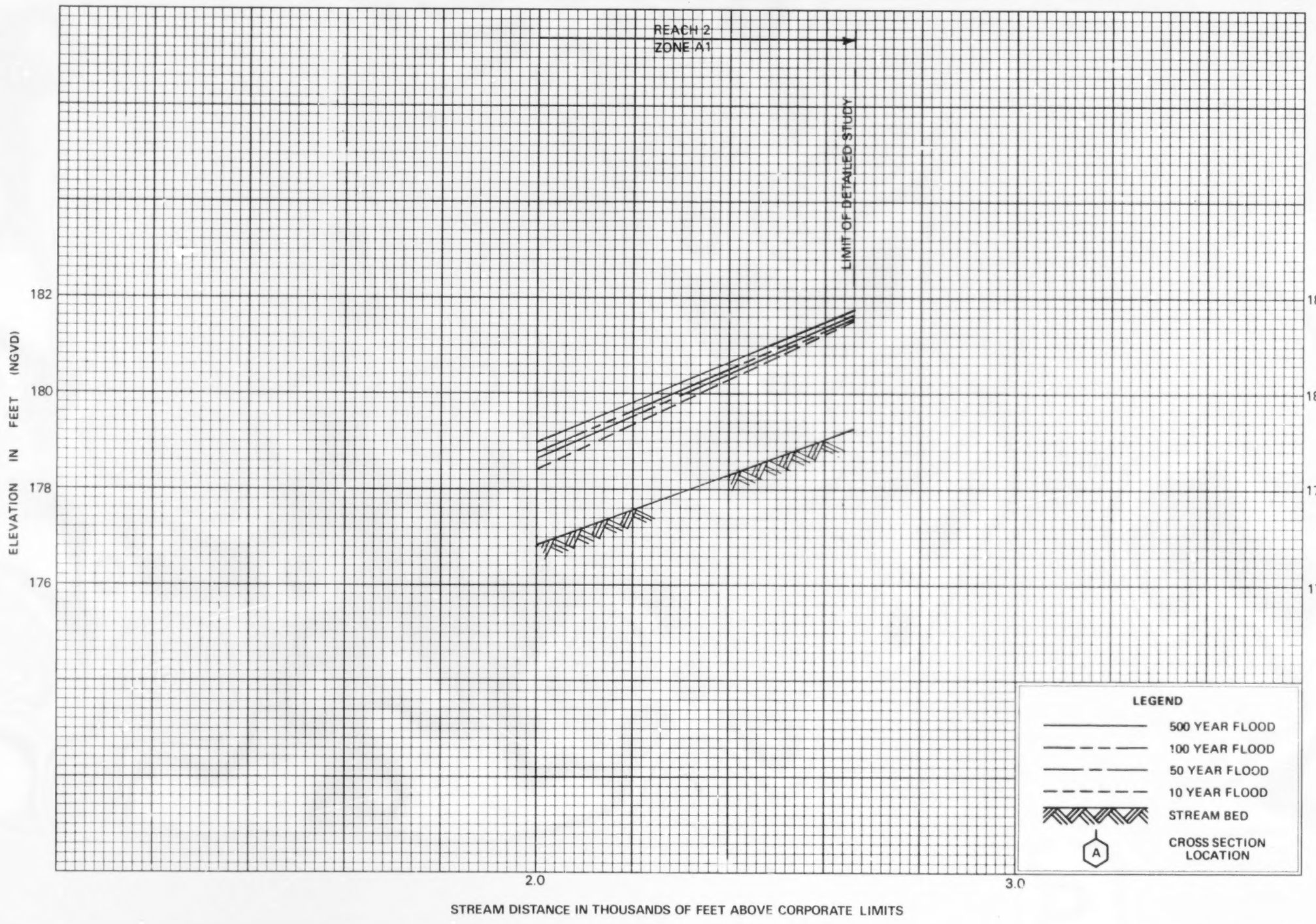
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

09P

BEST COPY AVAILABLE



FLOOD PROFILES

HOBBS BROOK

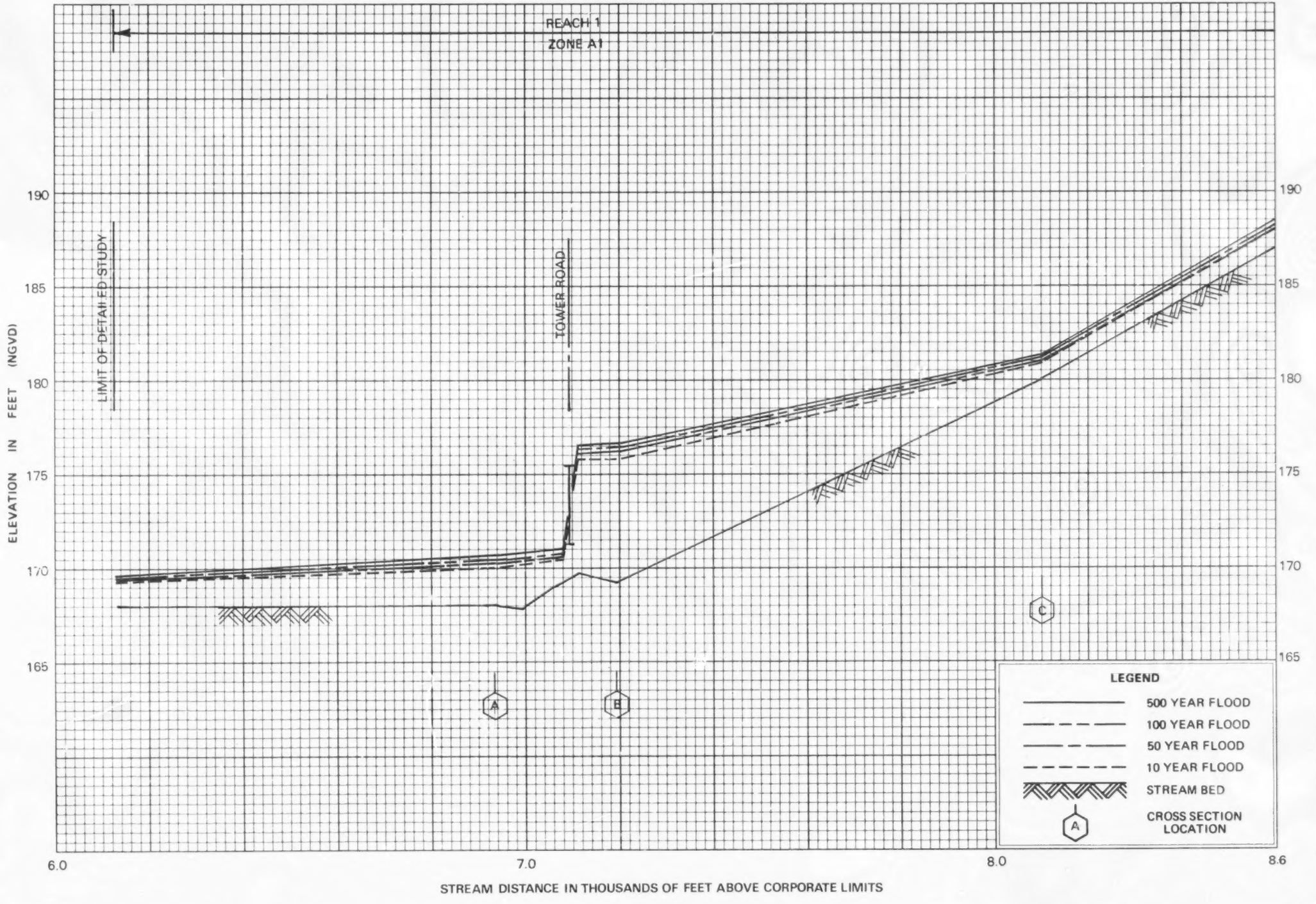
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

10P

BEST COPY AVAILABLE



FLOOD PROFILES

STONY BROOK

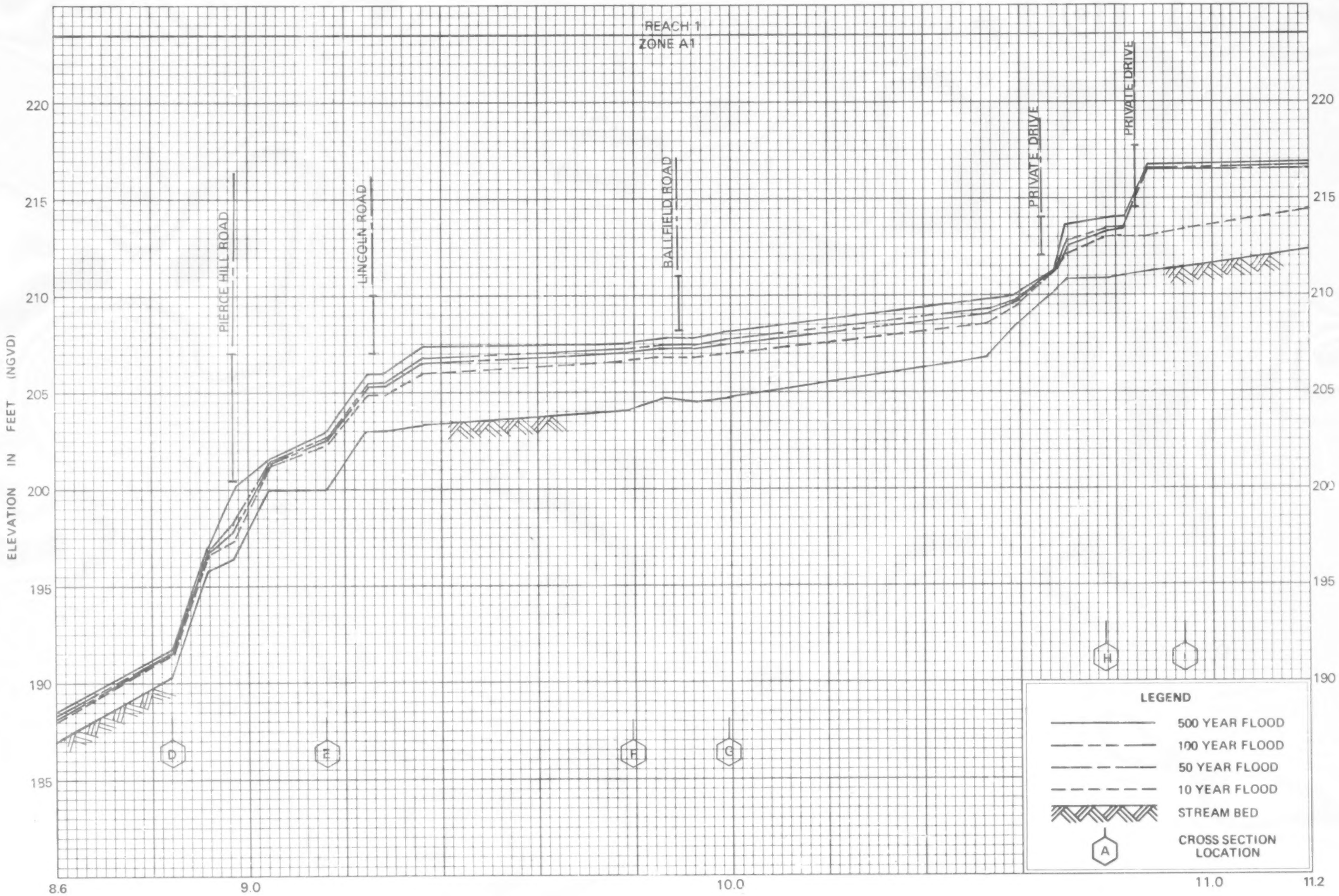
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

11P

BEST COPY AVAILABLE



FLOOD PROFILES

STONY BROOK

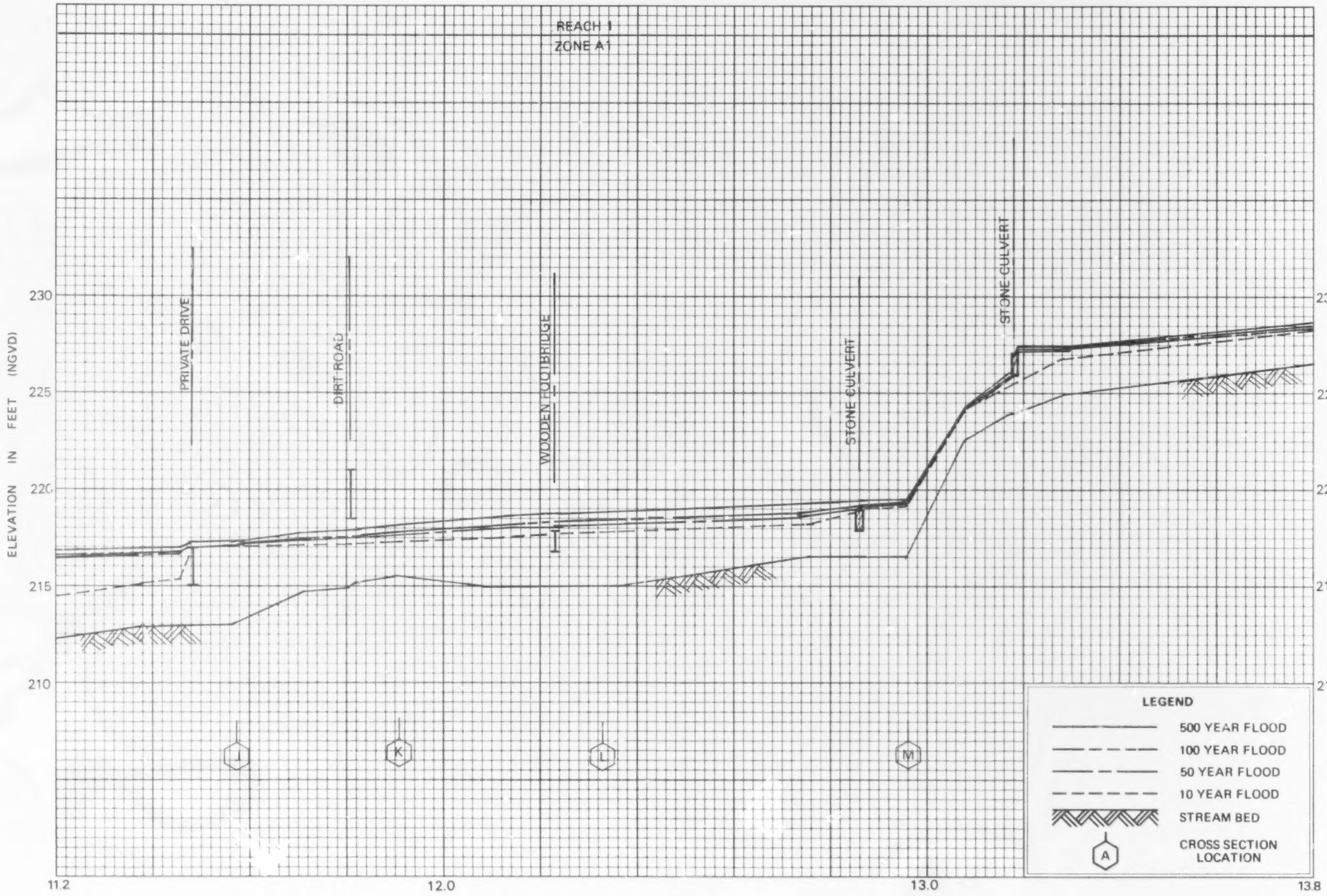
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

12 P

BEST COPY AVAILABLE



FLOOD PROFILES

STONY BROOK

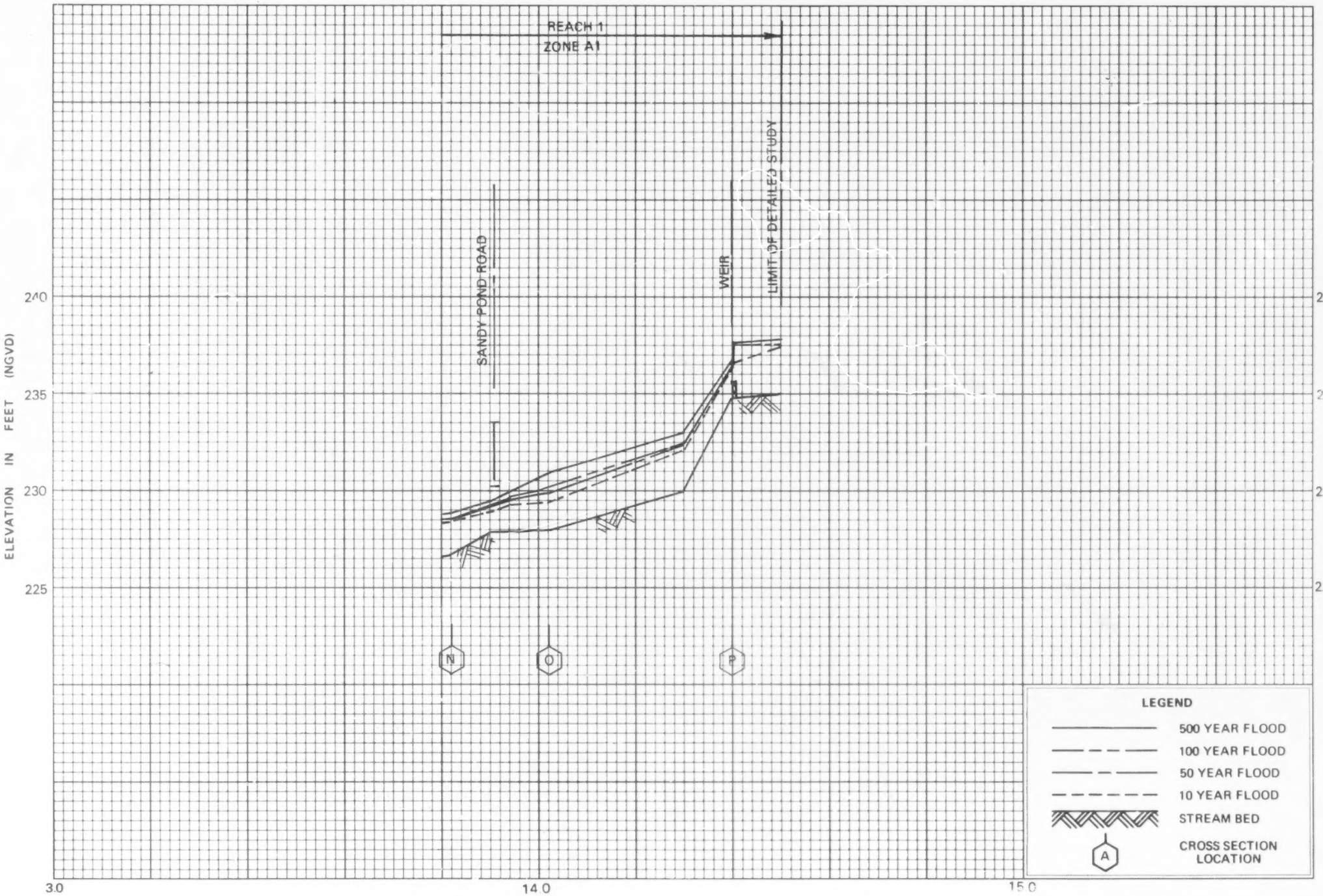
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

13P

BEST COPY AVAILABLE



FLOOD PROFILES

STONY BROOK

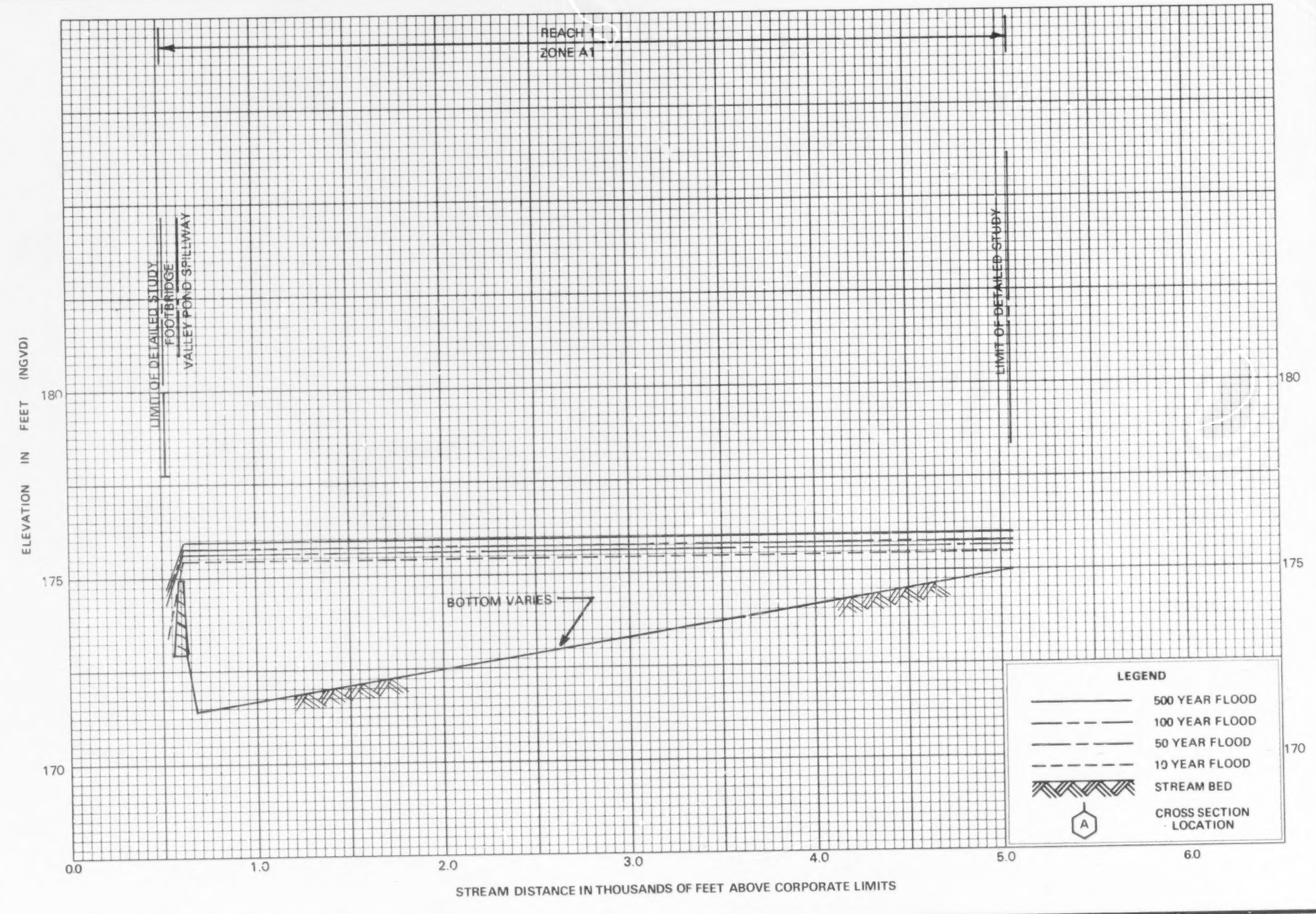
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

14P

BEST COPY AVAILABLE



FLOOD PROFILES

VALLEY POND

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF LINCOLN, MA

(MIDDLESEX COUNTY)

15P

BEST COPY AVAILABLE